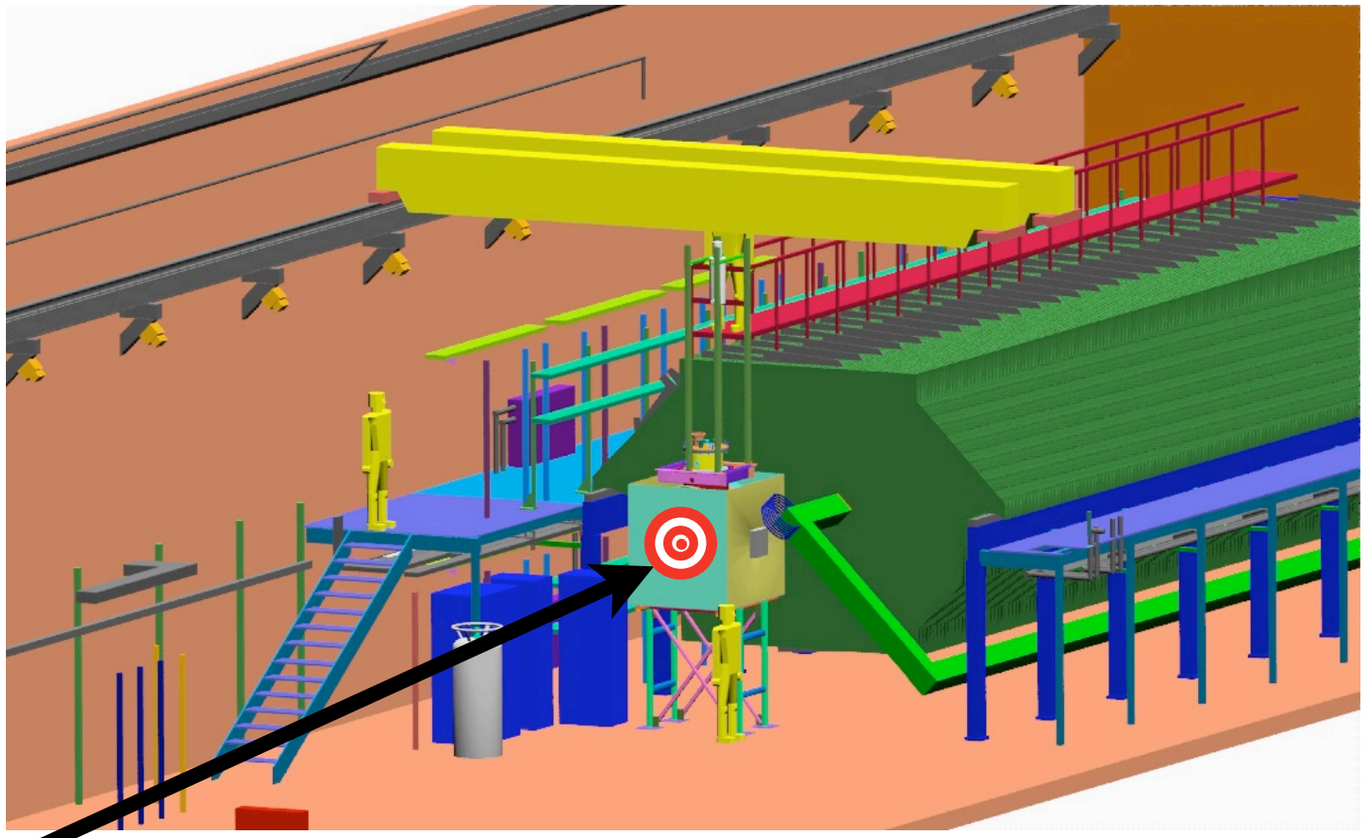
ArgoNeuT:
LArTPC R&D

Mitch Soderberg

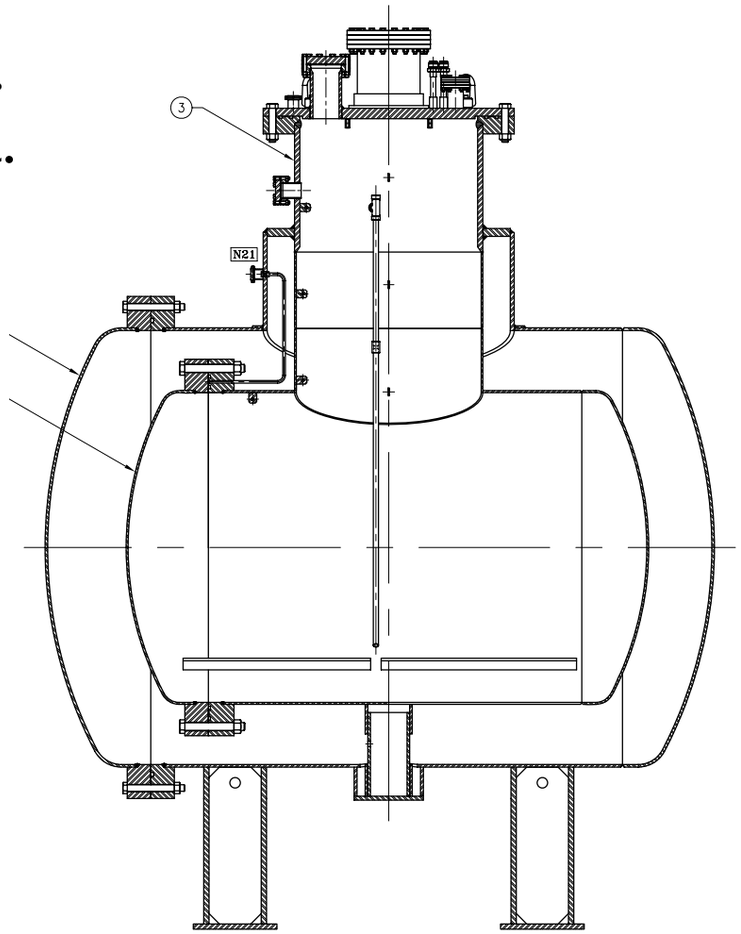
June 4, 2008

Introduction

- ArgoNeuT (a.k.a. - test experiment T962) is a ~175 liter Liquid Argon Time Projection Chamber
- Will sit in front of MINOS near detector in NuMI beamline. Use MINOS as a range stack.
- Jointly funded by NSF/DOE.
- Goals:
  - Gain experience building/running LArTPCs.
  - Accumulate a sample of neutrino events.
  - Confront all aspects of underground running and safety.
  - Develop simulation of LArTPCs and compare with data.



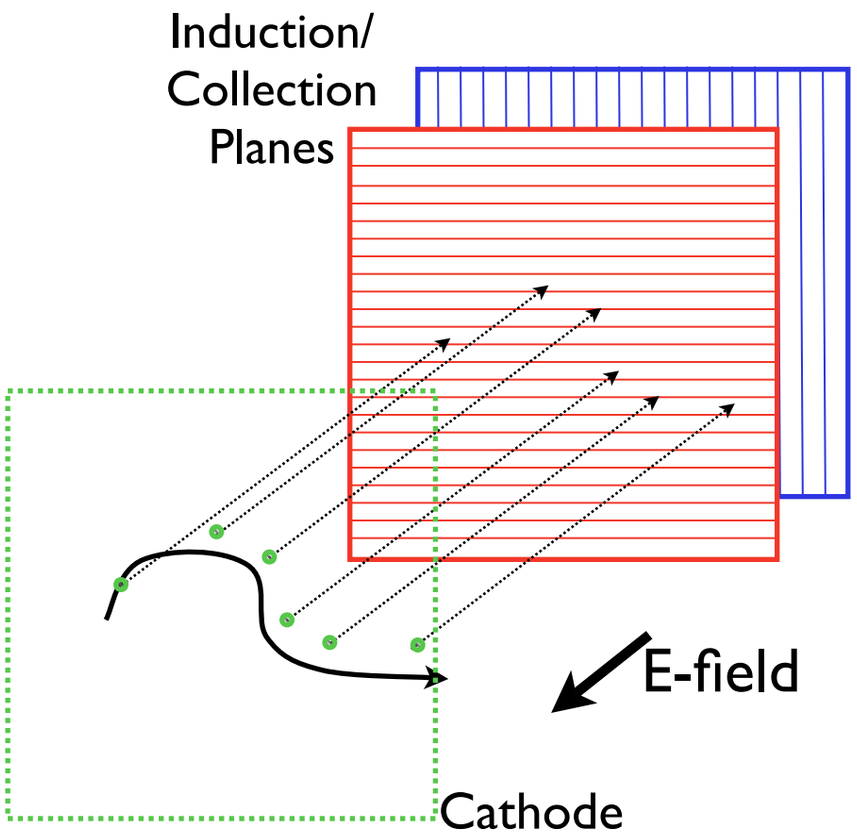
NuMI Tunnel



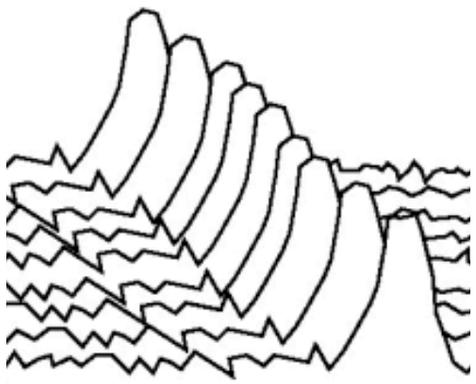
ArgoNeuT

LArTPC Principal

- Interactions inside TPC produce ionization particles that drift along electric field lines to readout planes.
- Scintillation light also present, can be collected by PMTs and triggered on.
- Knowledge of drift speed, and T_0 of events, can be used to reconstruct interaction.



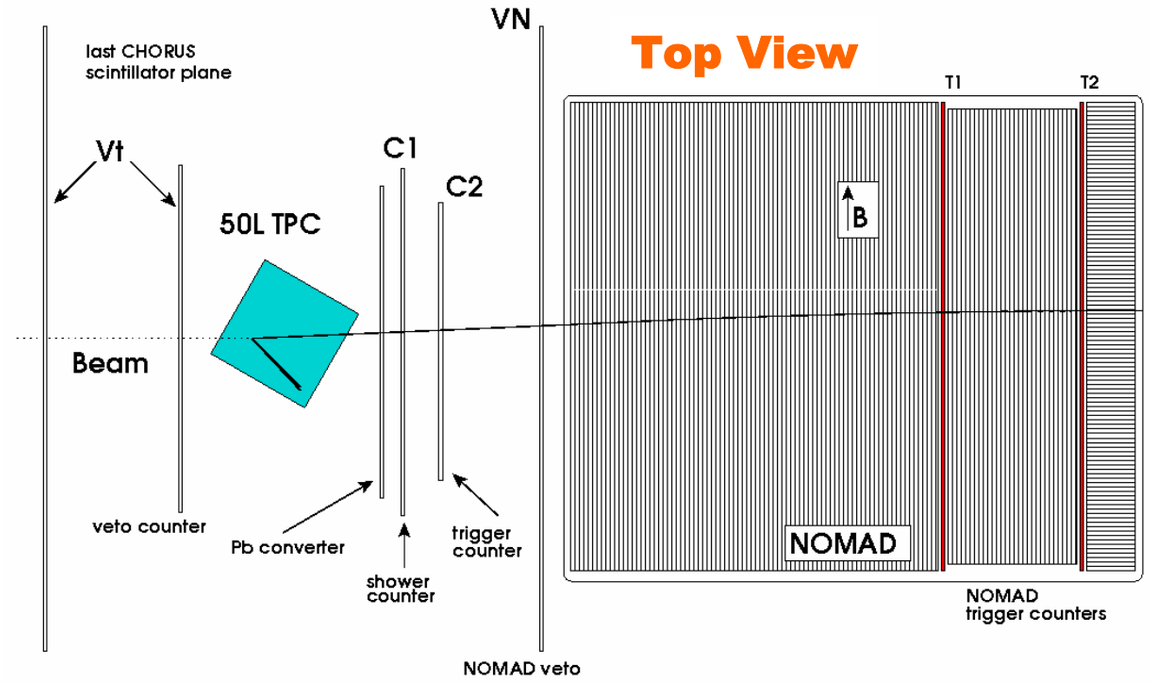
Train of pulses, with time offsets due to different drift lengths.

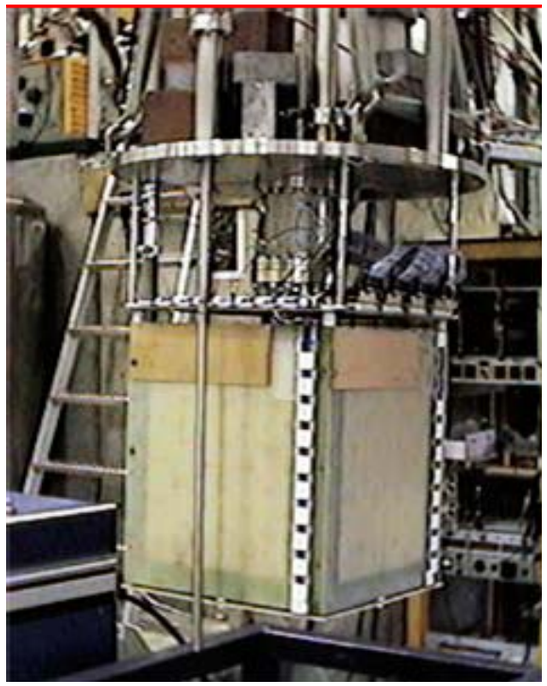


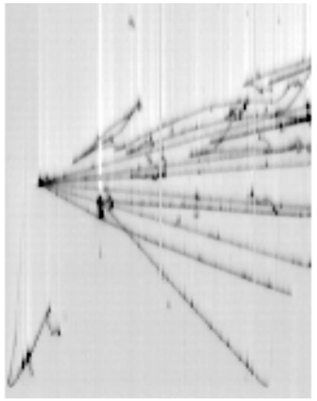
$$(t - T_0) = v_{drift} \cdot (x - x_{\text{wire}})$$

Test Stand Approach

- Small detectors setups allow us to study LArTPC performance.
- Only previous LArTPC to see neutrino beam was 50L TPC at CERN WANF beam in 1997.
  - Collected ~10000 ν_μ CC events







"A Study of Q.E. neutrino interactions with a 50L TPC at the WANF beam" - Alberto Martinez de la Ossa

- ArgoNeuT will improve over the 50L TPC in several aspects:
  - larger size (x3)
  - more events (45000 events in 180 days)
  - lower energy beam (~3 GeV vs ~25GeV)
  - stable running for many months.

ArgoNeuT Collaboration

F. Cavanna
University of L'Aquila

B. Baller, C. James, G. Rameika
Fermi National Accelerator Laboratory

M. Antonello, R. Dimaggio, O. Palamara
Gran Sasso National Laboratory

C. Bromberg, D. Edmunds, P. Laurens, B. Page
Michigan State University

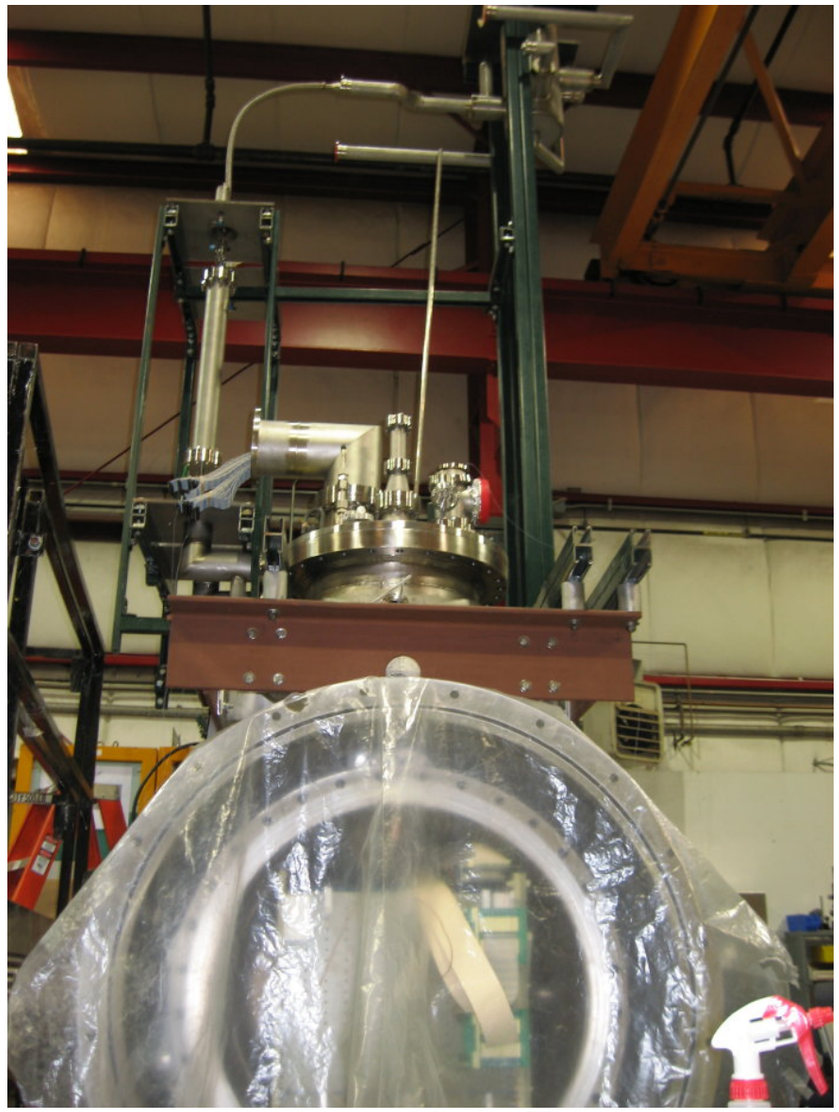
S. Kopp, K. Lang
The University of Texas at Austin

C. Anderson, B. Fleming*, S. Linden, M. Soderberg, J. Spitz, T. Wongjirad
Yale University

Cryostat

- Worked with Fermilab Cryo./Bartoszek Engineering to design.
- Built by PHPK of Columbus, Ohio
- Vacuum jacketed stainless steel cryostat with ~550 liter capacity.
- “Chimney” is used to make all vacuum penetrations.

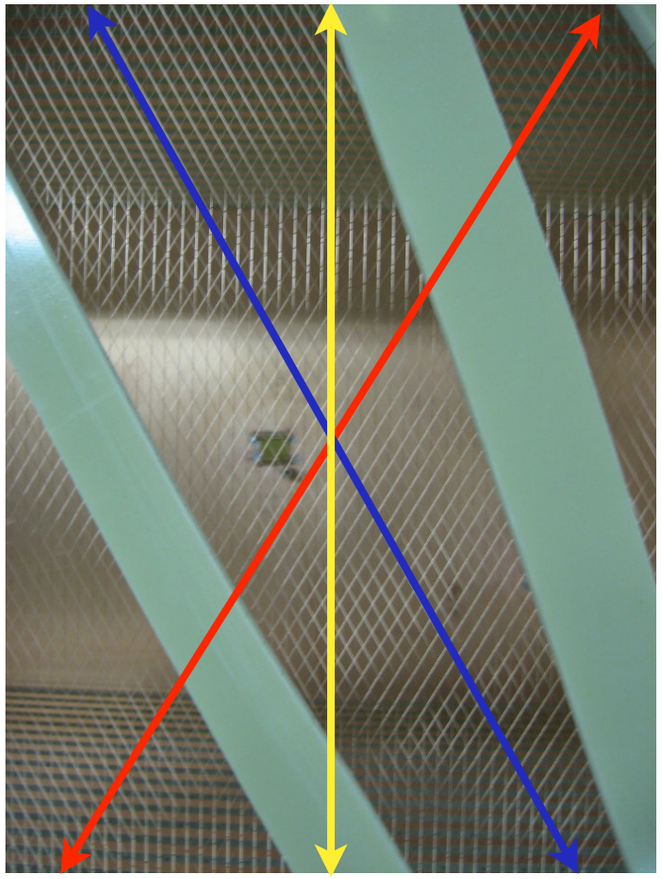
Arrival at FNAL



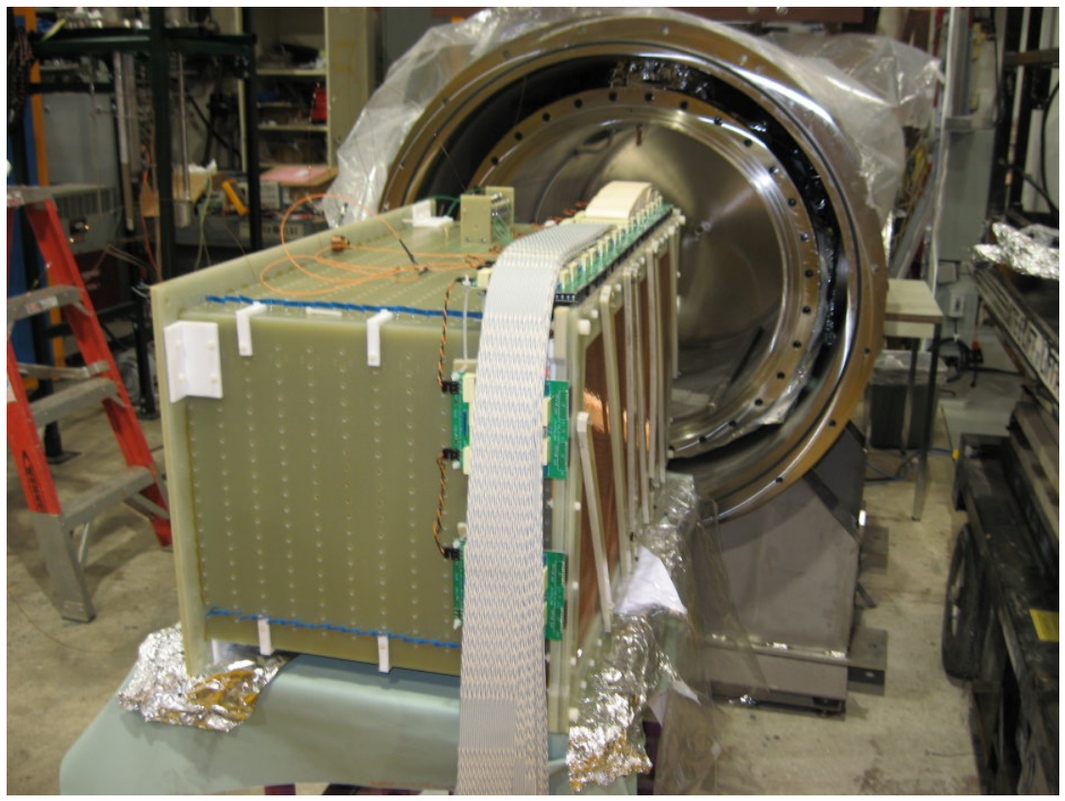
At PAB

TPC

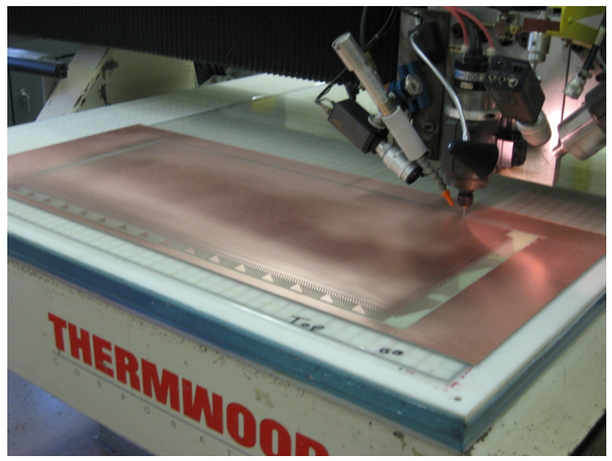
- 175 liter active volume, 480 channels of signal.
- Collection, Induction2, Induction1 planes. Induction1 plane not read out.
- 4mm wire pitch, 4mm plane spacing.
- 500V/cm electric field, Max. drift of ~50cm.
- Bias voltage distribution boards located directly on TPC.
- 0.15mm diameter BeCu wire. Cu-clad G10 used for field cage.
- G10 machining, wire stringing done by Fermilab staff.



Wire Orientations



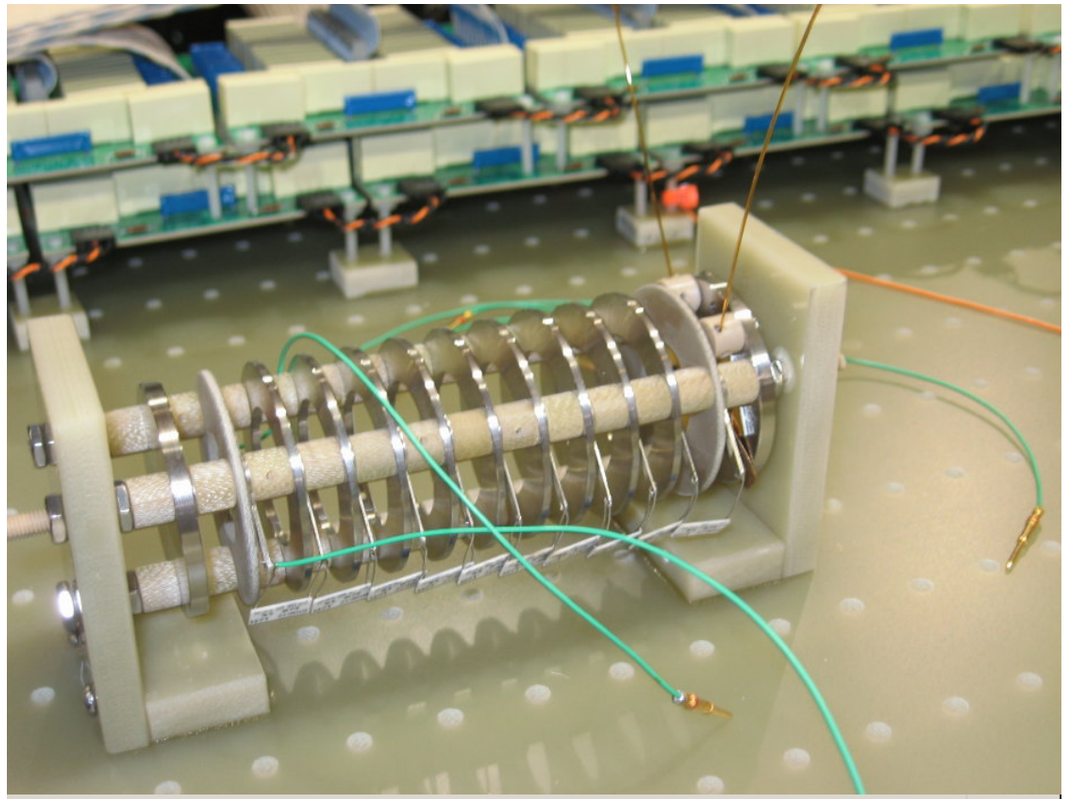
TPC About to Enter Cryostat



G10 Machining at Lab 8

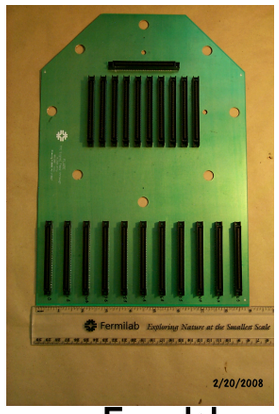
Purity Monitor

- Based on ICARUS design.
- Xenon flashlamp supplies light to photocathode, via two redundant 600μm quartz non-solarizable fibers.
- Smaller than typical purity monitor due to space constraints.
- Mounts directly on TPC.
- Photocathode is gold coated aluminum substrate.
- Fibers are difficult to deal with in these cryogenic systems....would like to study/improve this in future phase of ArgoNeuT.



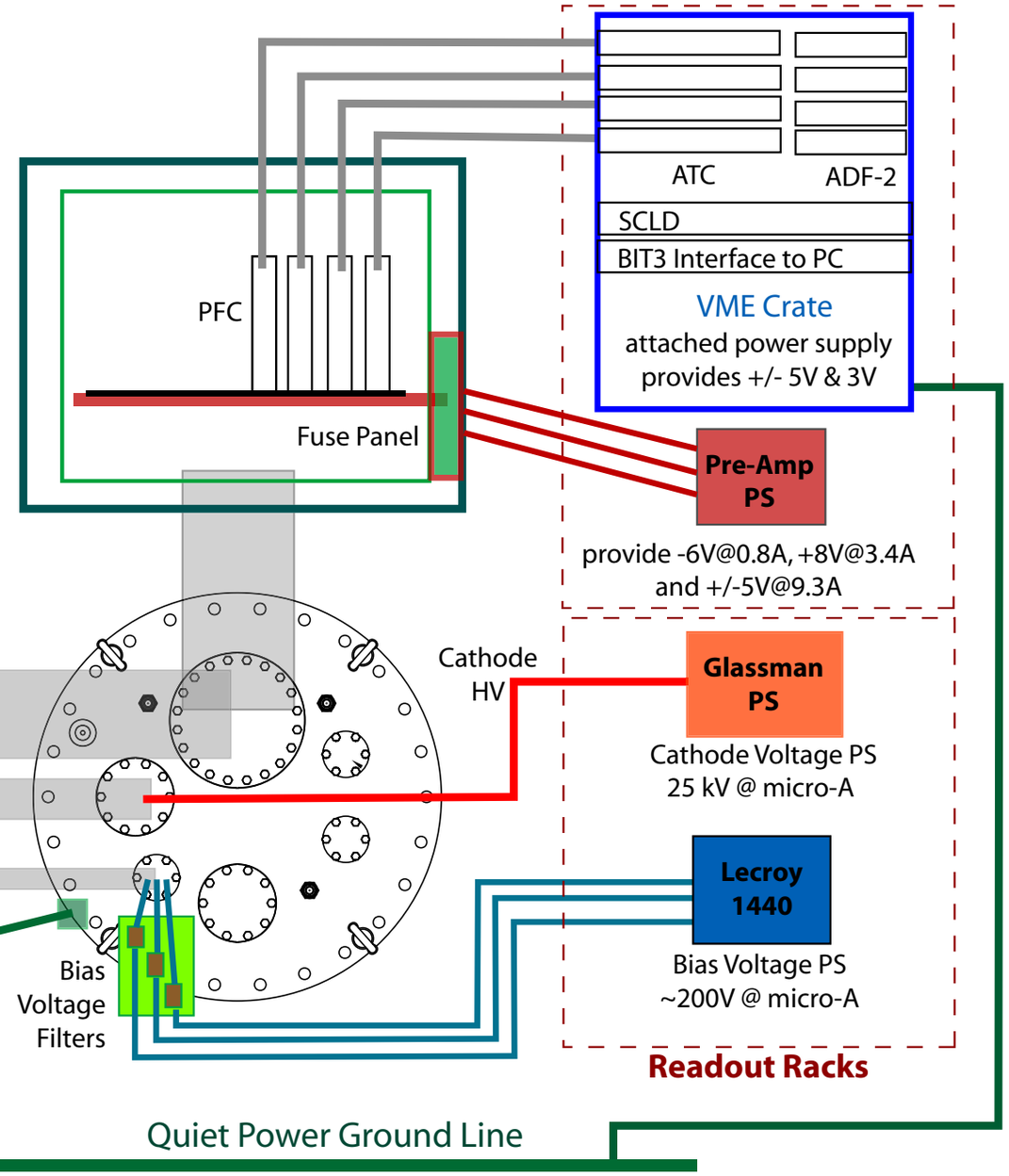
Electronics

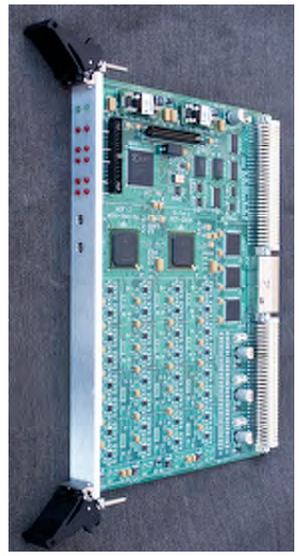
- 480 channels built by MSU
- Big step for U.S. to have home brewed electronics.



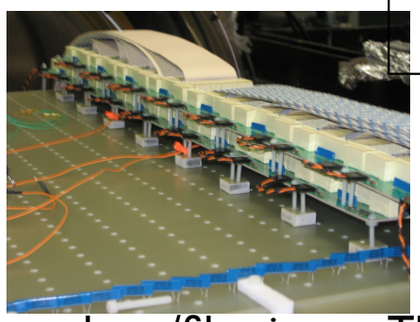
Vacuum Feedthrough
(FNAL designed)

Electronics Box
attached to top flange

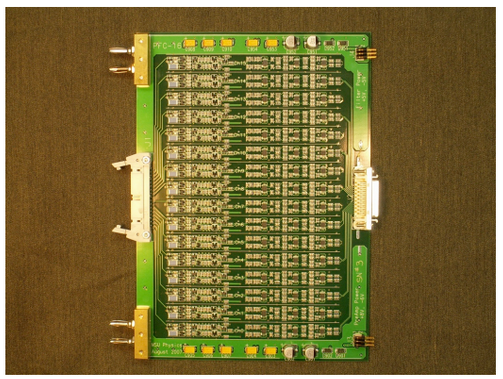




Digitization



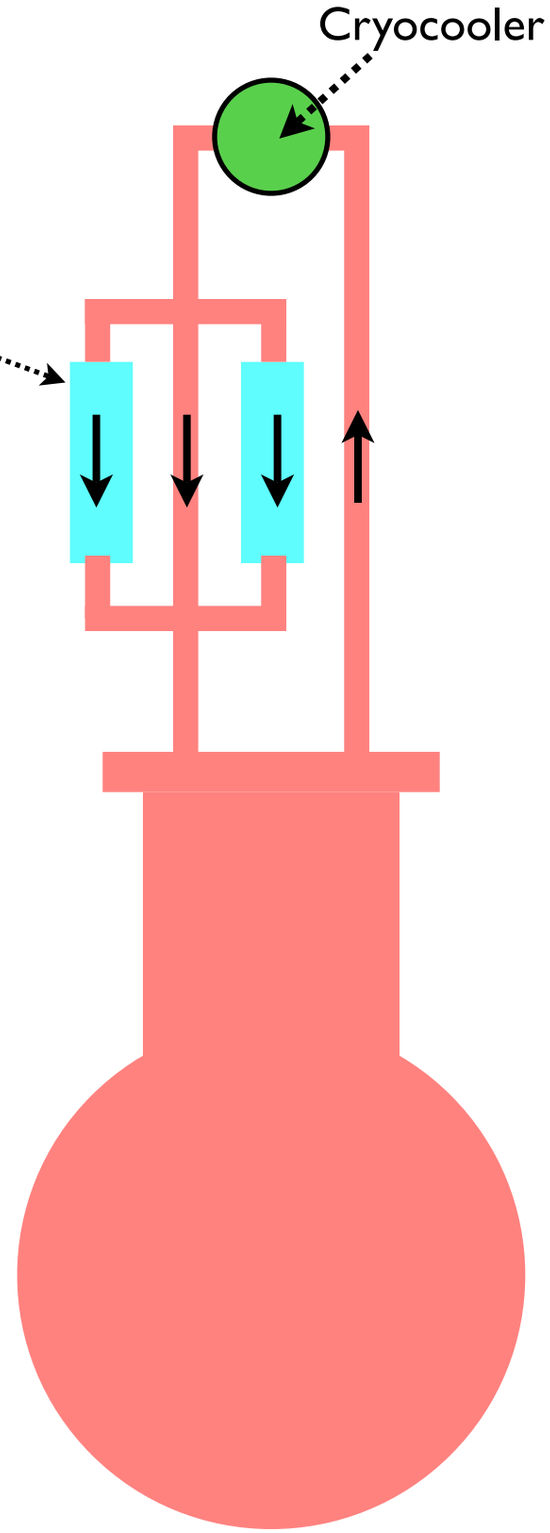
Bias voltage/filtering on TPC:
Improvement over ICARUS



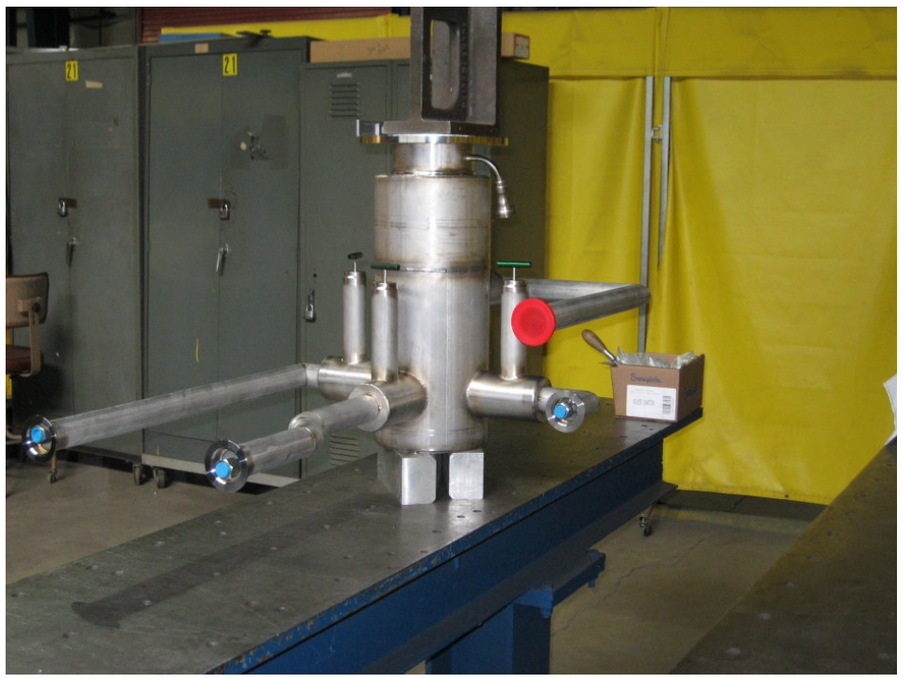
Preamp Card

Cryogenics

- Self-contained system.
- Recirculate argon through Trigon filter.
- Cryocooler used to condense boil-off gas.
- Multiple relief paths to achieve safe running.



300W Cryocooler

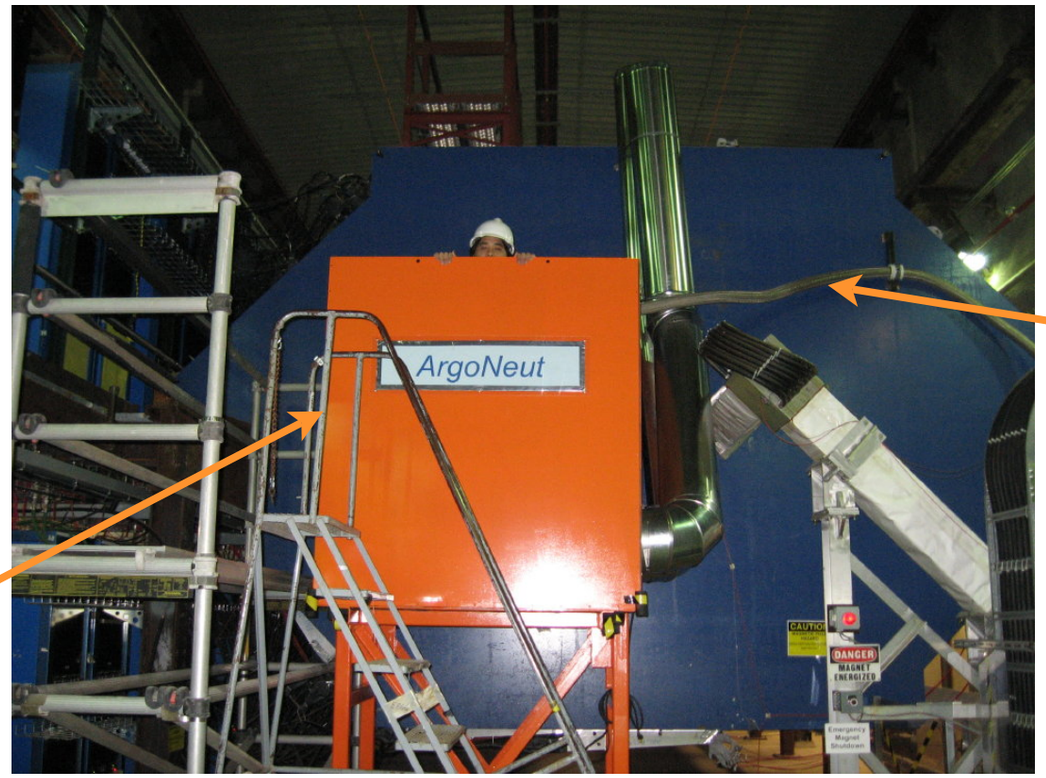


Cryocooler Housing
(FNAL design/assembly)

Underground

Many safety issues addressed to prepare for move underground and maintain ODH-0 rating of tunnel:

- ArgoNeuT sits in a bathtub, which acts as tertiary containment in case both cryostats fail.
- Relief piping is routed to vent line (runs up and out shaft), to ensure no argon released in tunnel.
- 2 ODH monitors to alarm if leak is detected.
- Slow control system mirrored on screens in tunnel and surface building, and online, to alert of any ODH hazards before entering tunnel.

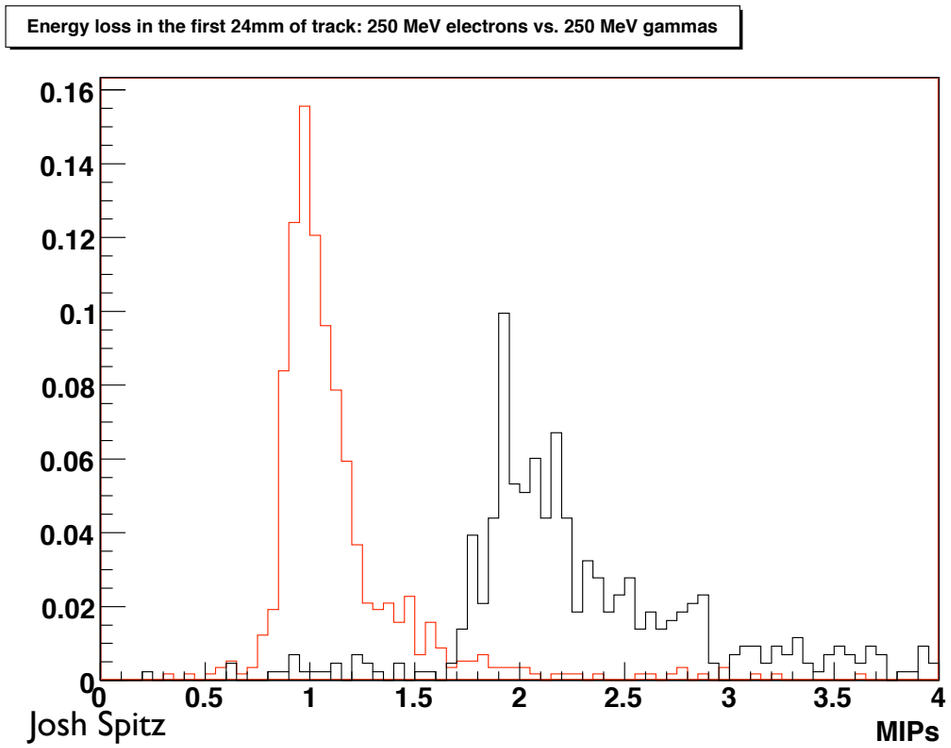


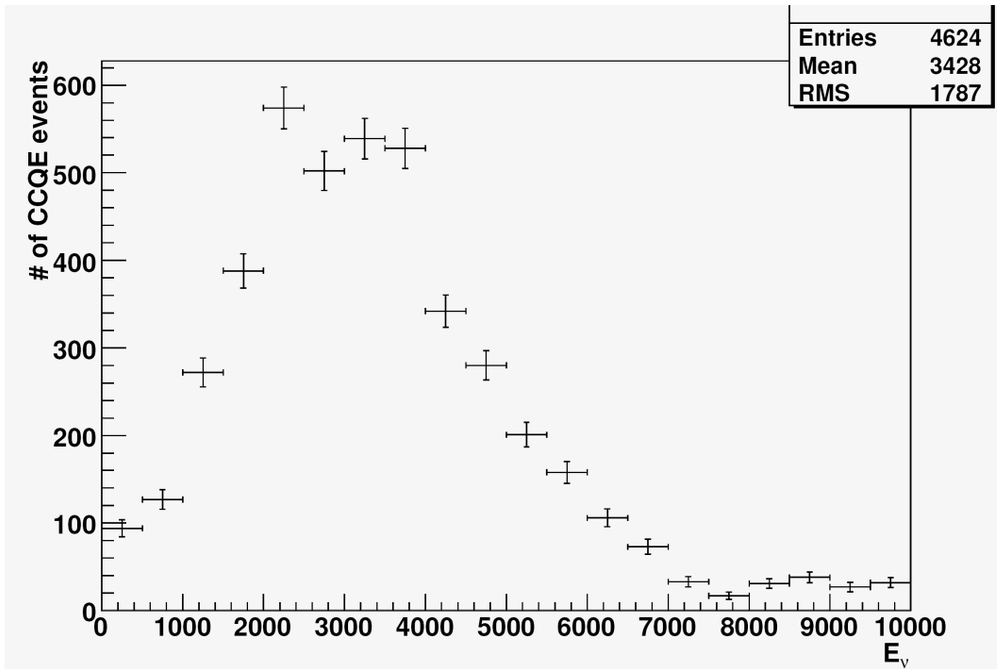
Bathtub

Vent Line

Physics Goals

Event Type	# in ArgoNeuT/day (0.8×10^{17})
ν_μ CC	160
$\overline{\nu_\mu}$ CC	14
ν_e CC	3
NC	54
Total	231





- Electron/gamma separation - Prove claims about superior separation ability of LArTPCs using dE/dx tag.
- Collect large sample of CCQE events, measure cross-section
- Develop realistic simulation of LArTPCs

Conclusion

- ArgoNeuT is an important milestone in the U.S. for LArTPC development.
- Fermilab support has been essential for constructing ArgoNeuT.
- Real data/experience will be invaluable in substantiating the case for LArTPCs in the U.S.
- Running very soon!

BACK UP SLIDES

Noble Liquids: Properties

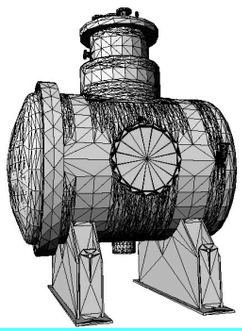
- Ionization and scintillation light used for detection (transparency to own scintillation).
- Ionization electrons can be drifted over long distances in these liquids.
- Very good dielectric properties allow high-voltages in detector.
- Argon is cheap and easy to obtain (1% of atmosphere).

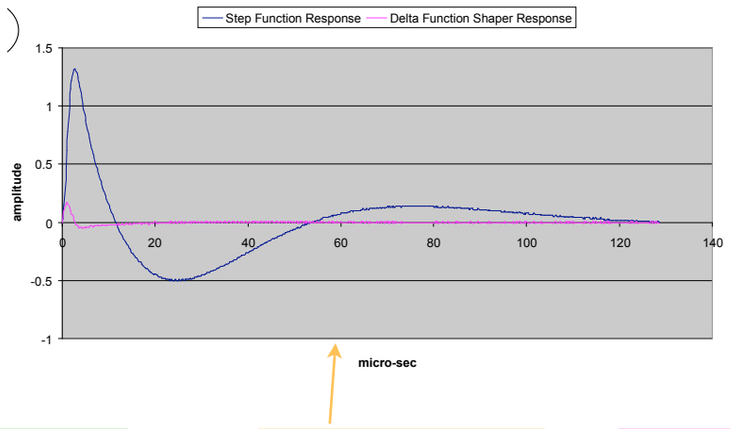
	Water	He	Ne	Ar	Kr	Xe
Boiling Point [K] @ 1atm	373	4.2	27.1	87.3	120.0	165.0
Density [g/cm^3]	1	0.125	1.2	1.4	2.4	3.0
Radiation Length [cm]	36.1	755.2	24.0	14.0	4.9	2.8
Scintillation [γ /MeV]	-	19,000	30,000	40,000	25,000	42,000
dE/dx [MeV/cm]	1.9		1.4	2.1	3.0	3.8
Scintillation λ [nm]		80	78	128	150	175

Simulation

- ArgoNeuT members (M. Antonello, B. Baller, Yale group, etc...) developing GEANT3/4 simulations for LArTPCs
- Simulation is general purpose for future LArTPCs.
- Goal is automated event reconstruction

CAD geometry in GEANT4





Neutrino Generator Interface

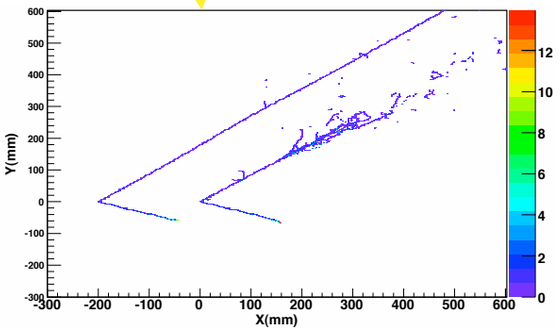
Geometry Description

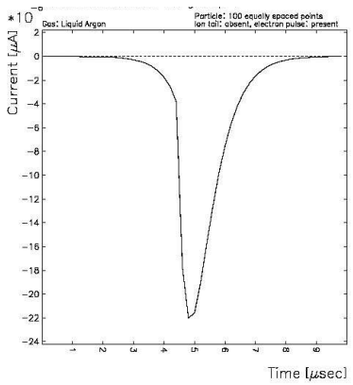
Pulse Formation

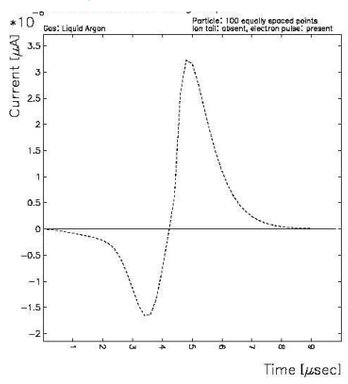
Electronics Simulation

Signal Processing

Automated Reconstruction







Collection/Induction Signals